Depth contolled ^{8}Li β-NMR and Physics at Interfaces

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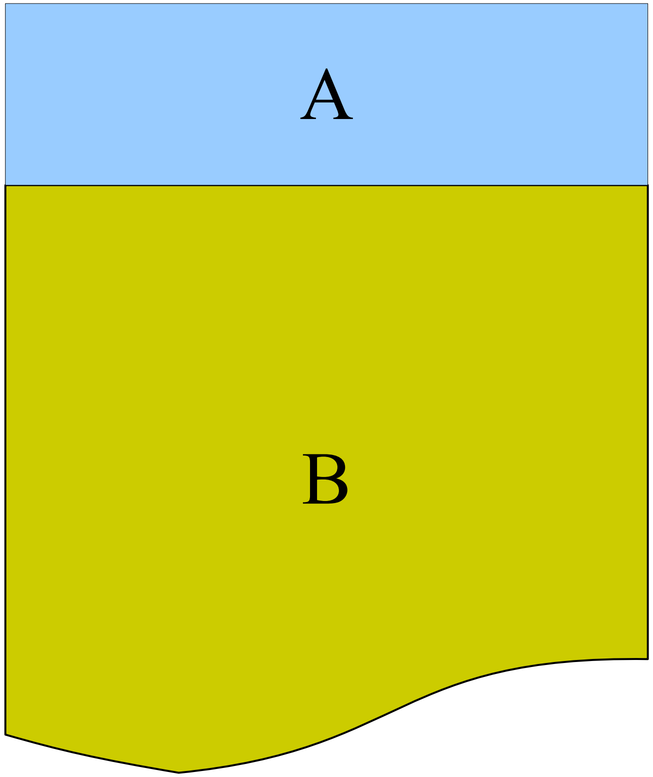
Outline

- Introduction
- The β-NMR technique
- Examples of applications
  - Magnetic multilayers – GMR.
  - Monolayers of single molecule magnets
  - Surfaces of superconductors
- Summary and Conclusions

Introduction: Bulk vs. Interface



What happens near and interface?

- We go from 3D to 2D system
- Changes in magnetic, electronic and structural properties.

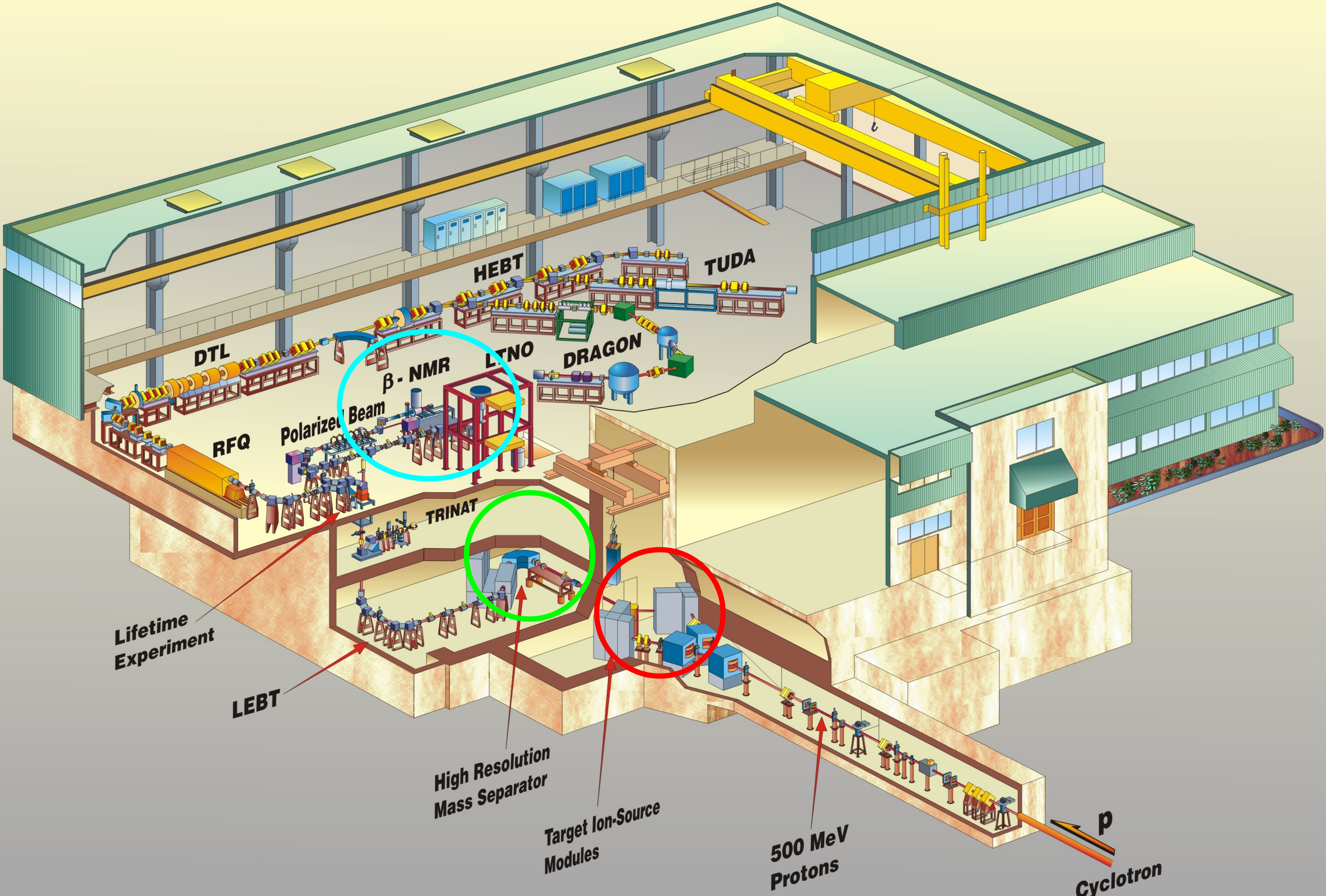
Questions:

- How/why do the properties change?
- What is the length scale of changes?
- Can we classify these changes?

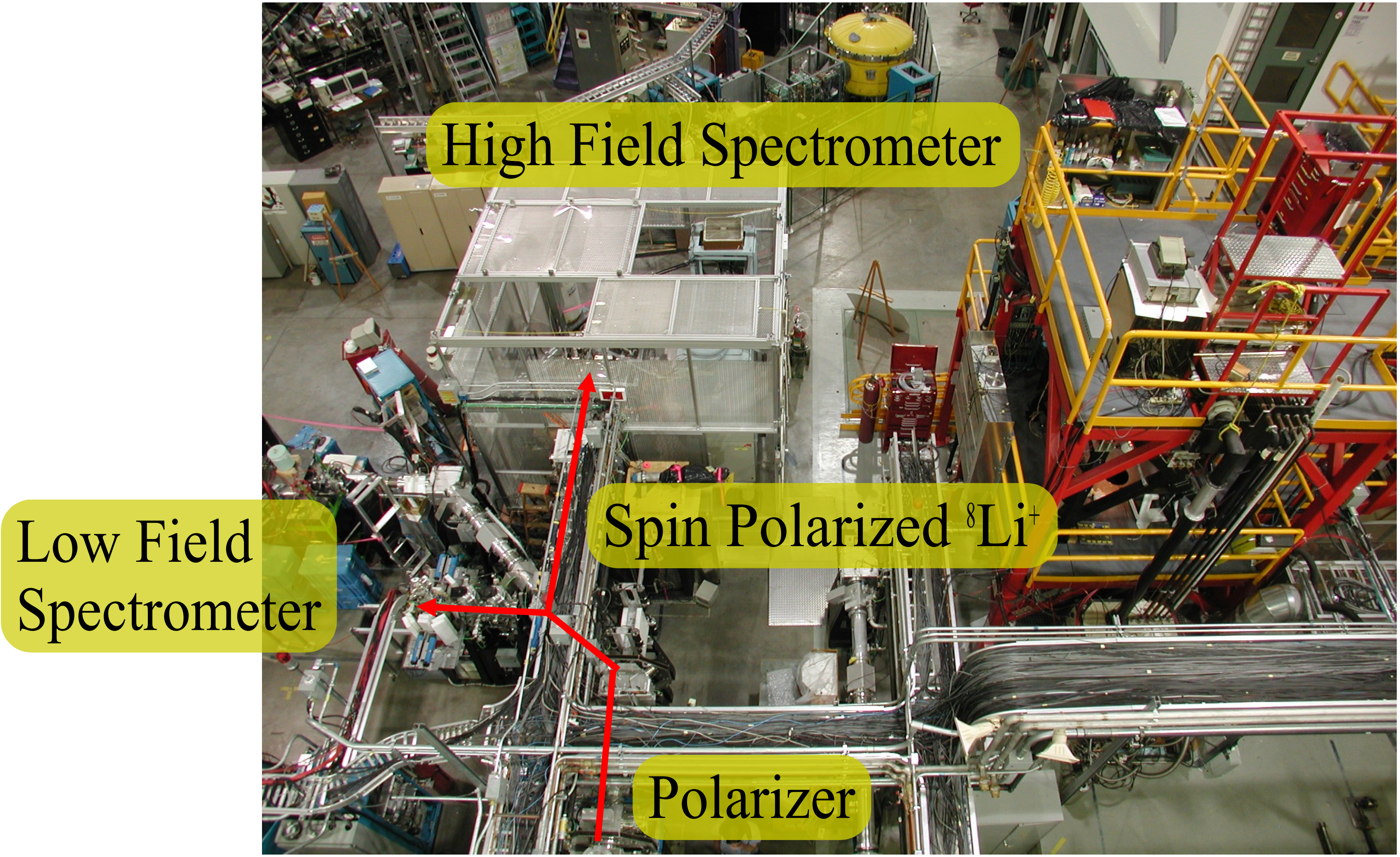
Motivation:

- Better understanding of *both bulk and interface*
- Application in devices.

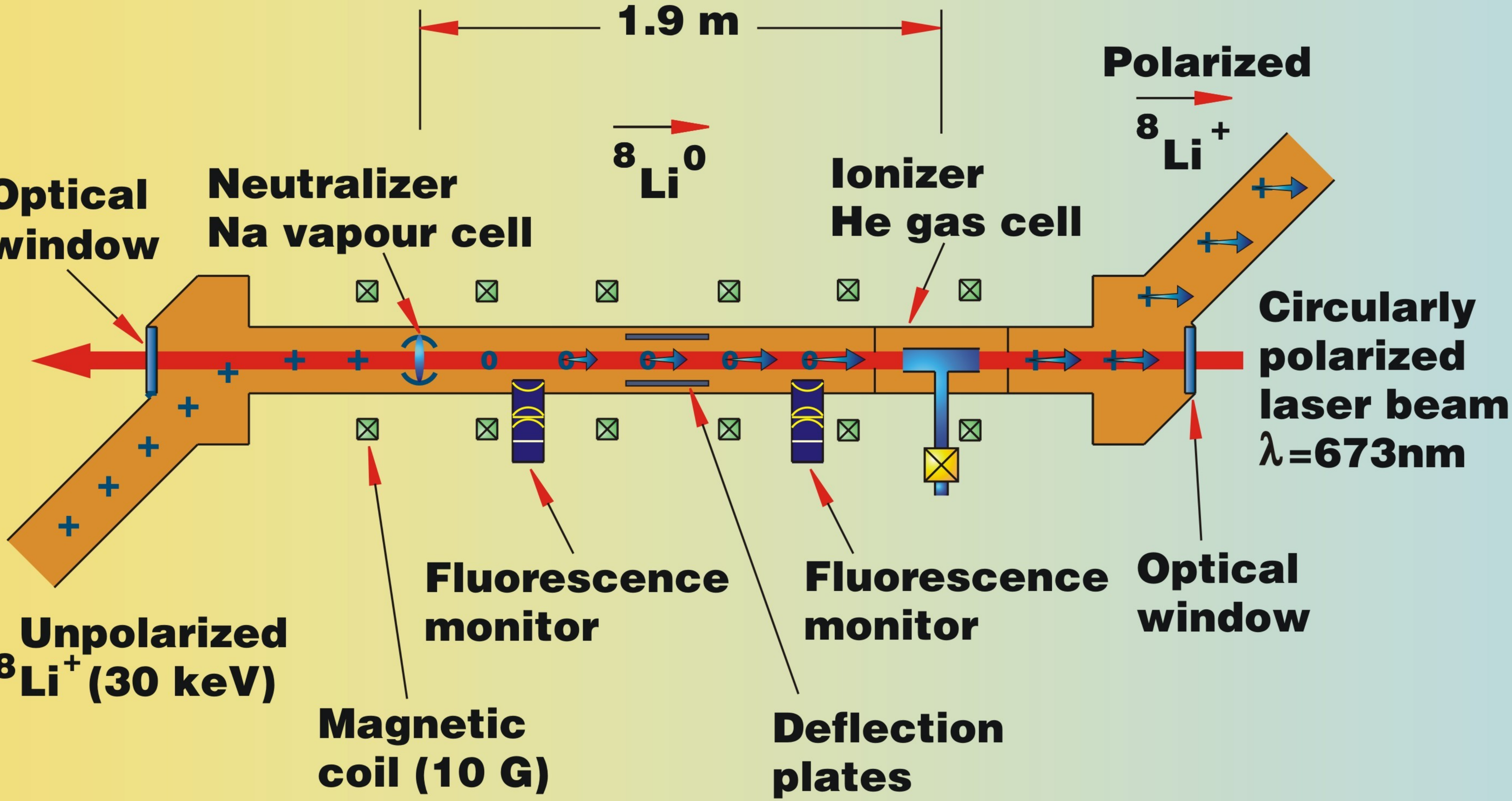
ISAC at TRIUMF



The β-NMR Facility at ISAC/TRIUMF



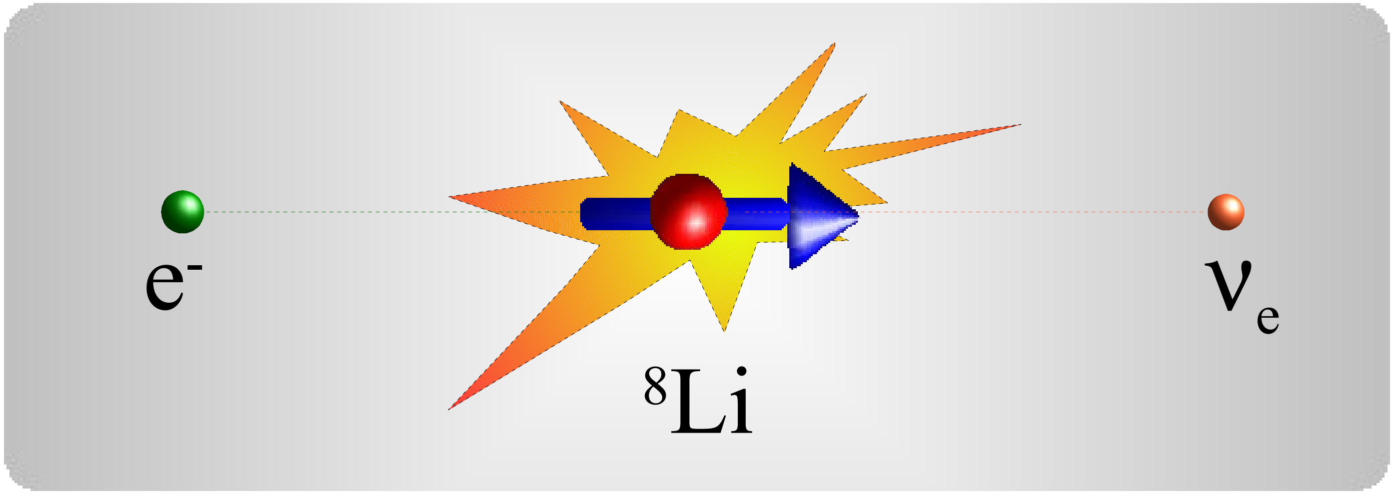
ISAC Neutralizer / Polarizer / Ionizer

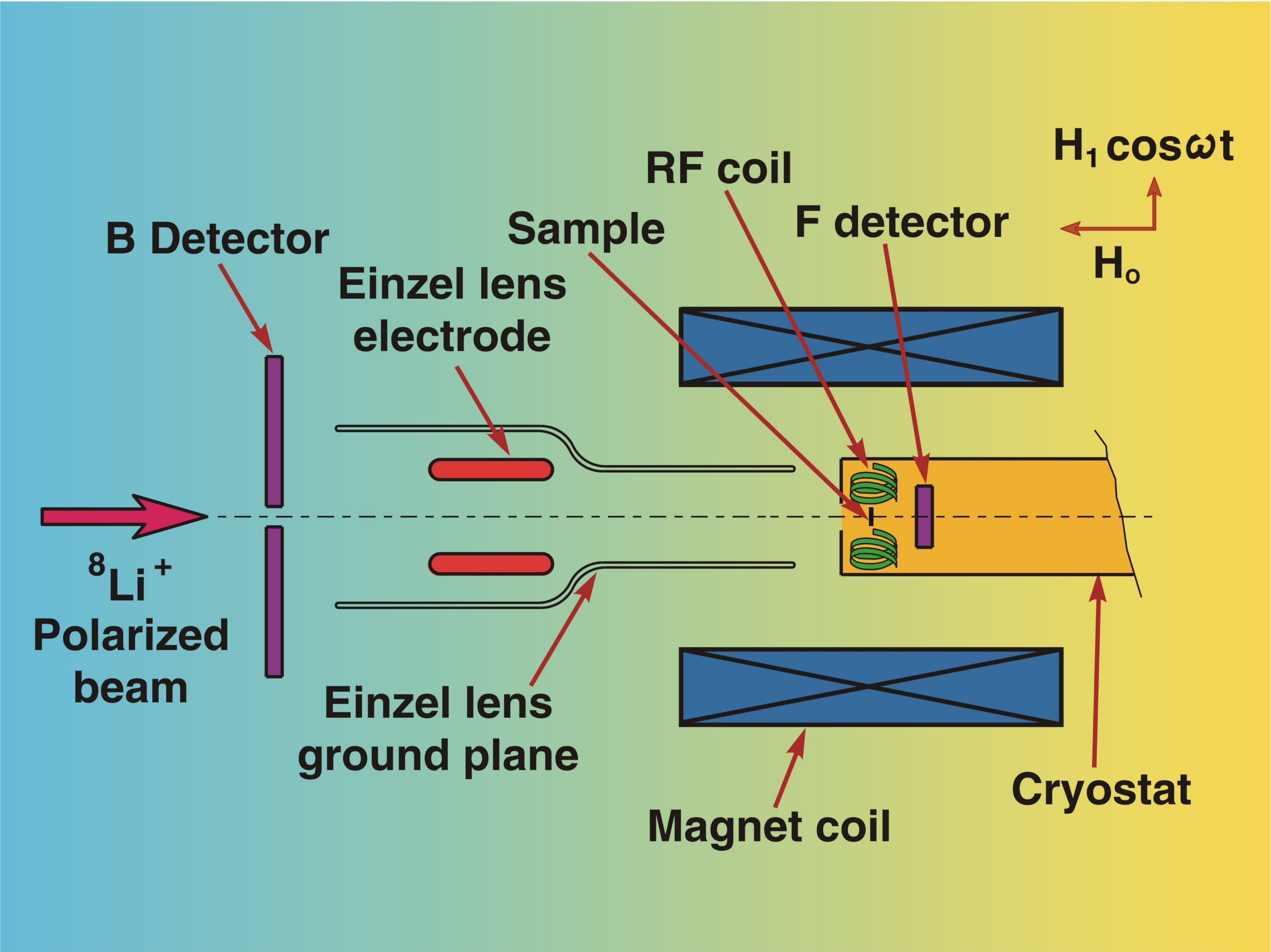


^{8}Li Nuclear β Decay

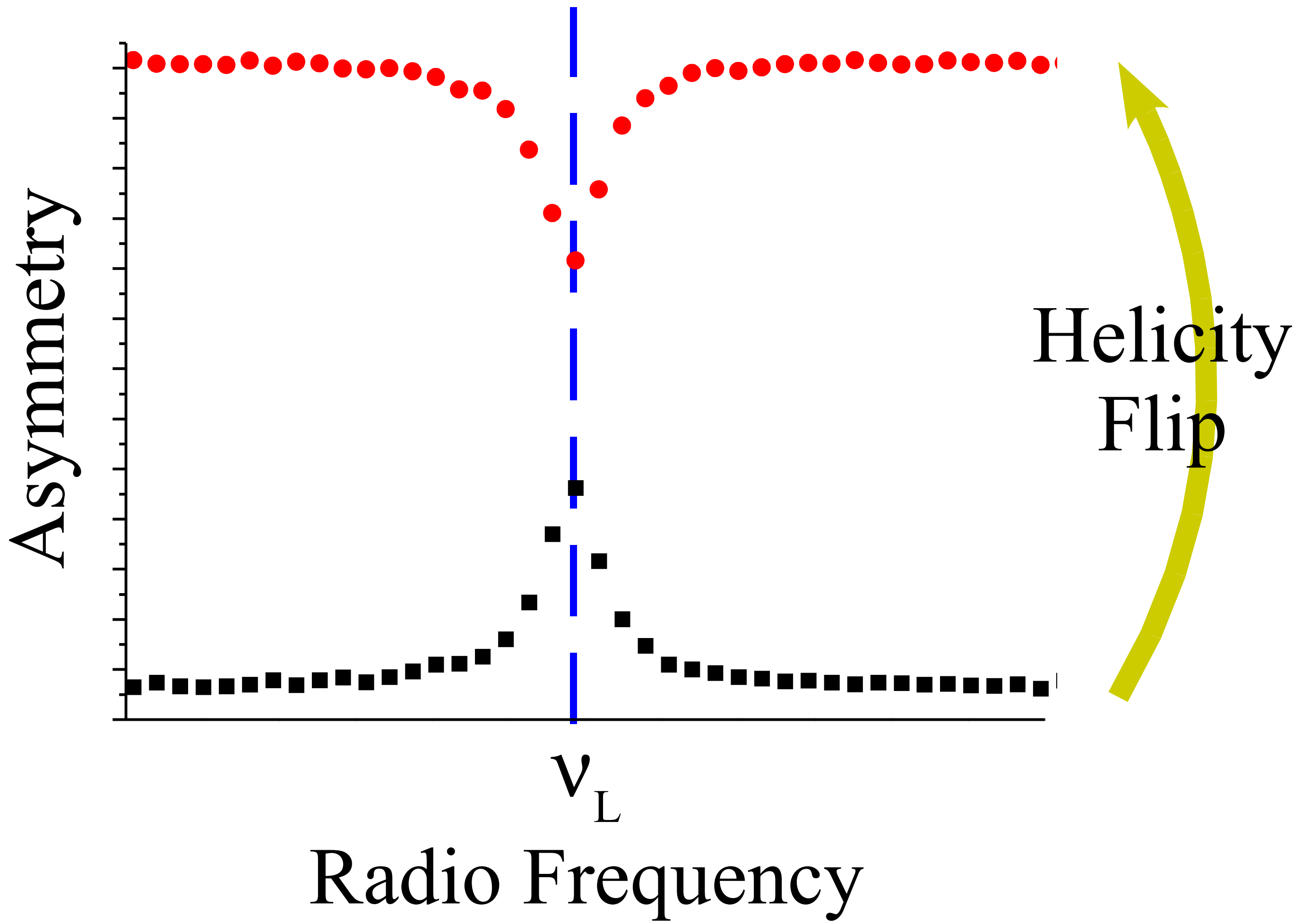
Spin I=2, Q=30.3 mb
γ=6.3 Mhz/T
$\langle A \rangle$=1/3 τ=1.2s

$$^{8}\text{Li} \longrightarrow {}^{8}\text{Be} + e^{-} + \nu_e$$




B Detector
Einzel lens electrode
Sample
RF coil
F detector
$H_1 \cos\omega t$
H_o
$^8Li^+$
Polarized beam
Einzel lens ground plane
Magnet coil
Cryostat

β-NMR Measurement

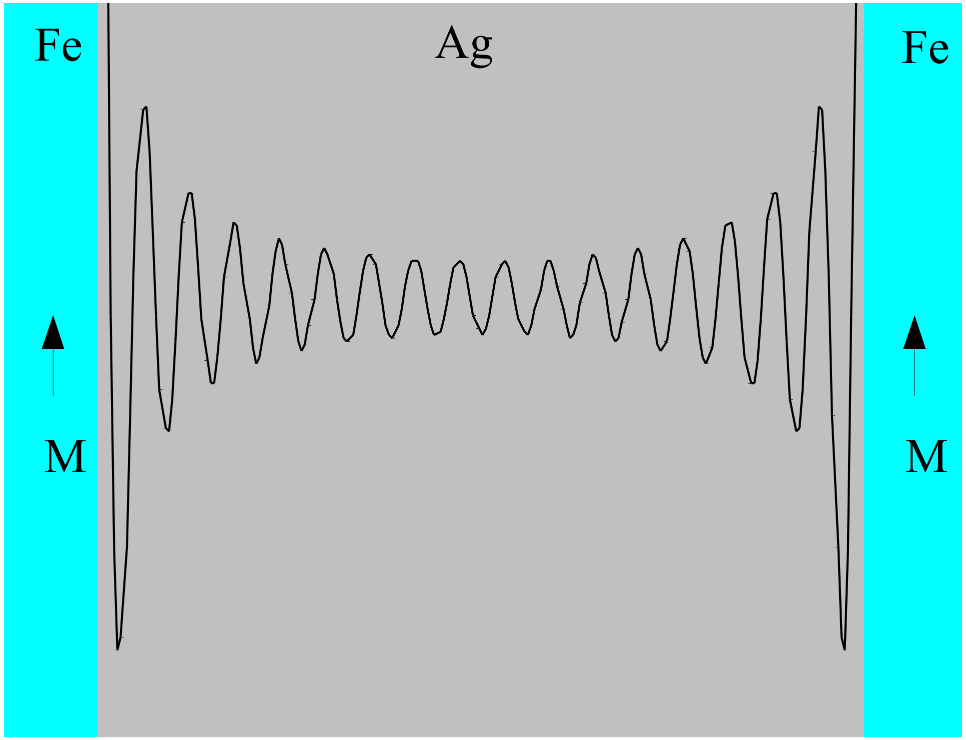


Example 1:

Induced hyperfine fields in magnetic multilayers

Introduction:

Induced Hyperfine Fields



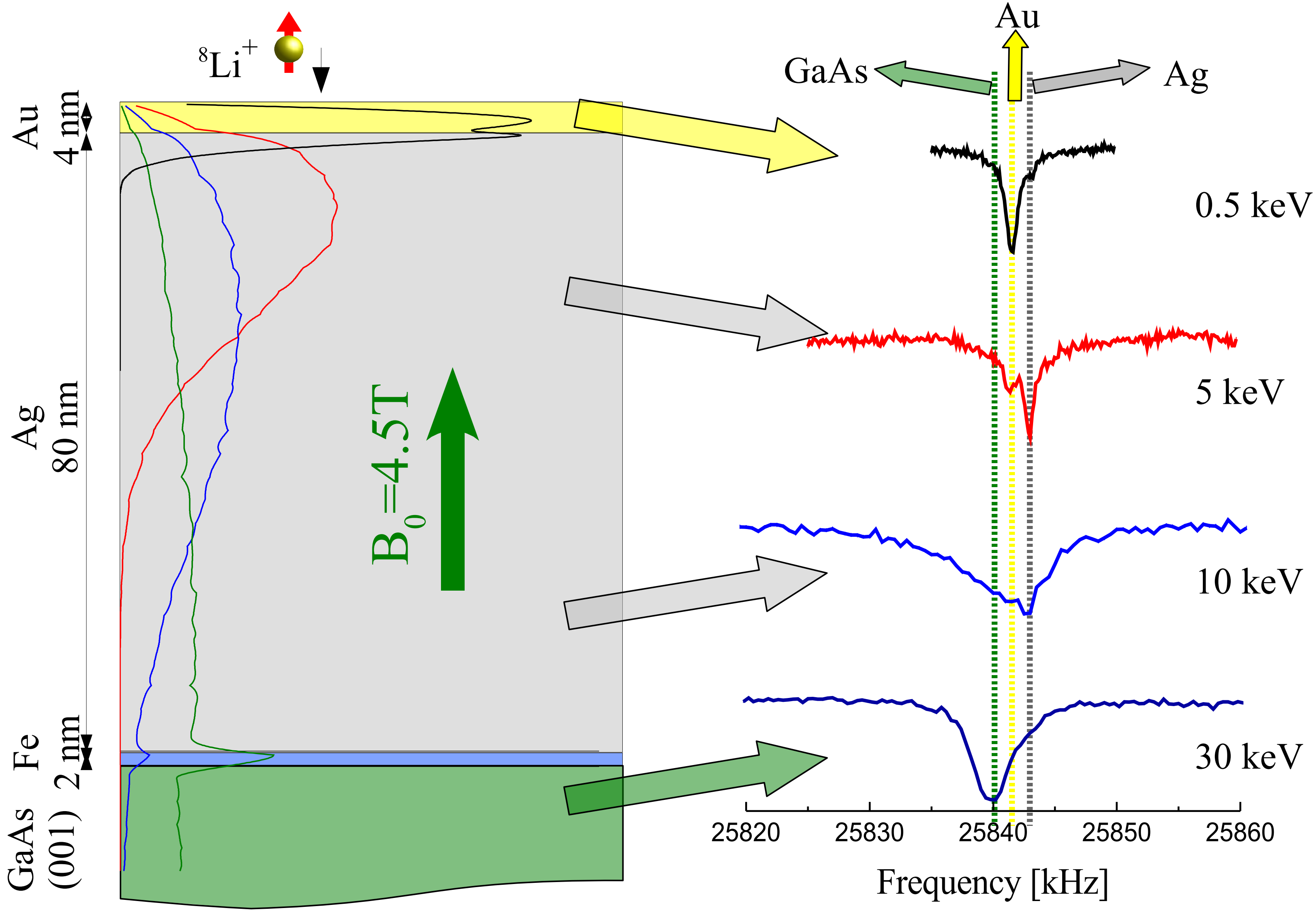
•Away from the interface, the induced field follows the asymptotic form

$$B(x) = \sum_{i=0}^{1} B_i \left(\frac{x}{\lambda_i}\right)^{-\alpha} \sin\left(\frac{2\pi x}{\lambda_i} + \phi_i\right)$$

λ_i - depends on the details of the Fermi surface

α=-2 according to the RKKY model

β-NMR Results in Au(4nm)/Ag(80nm)/Fe(2nm)

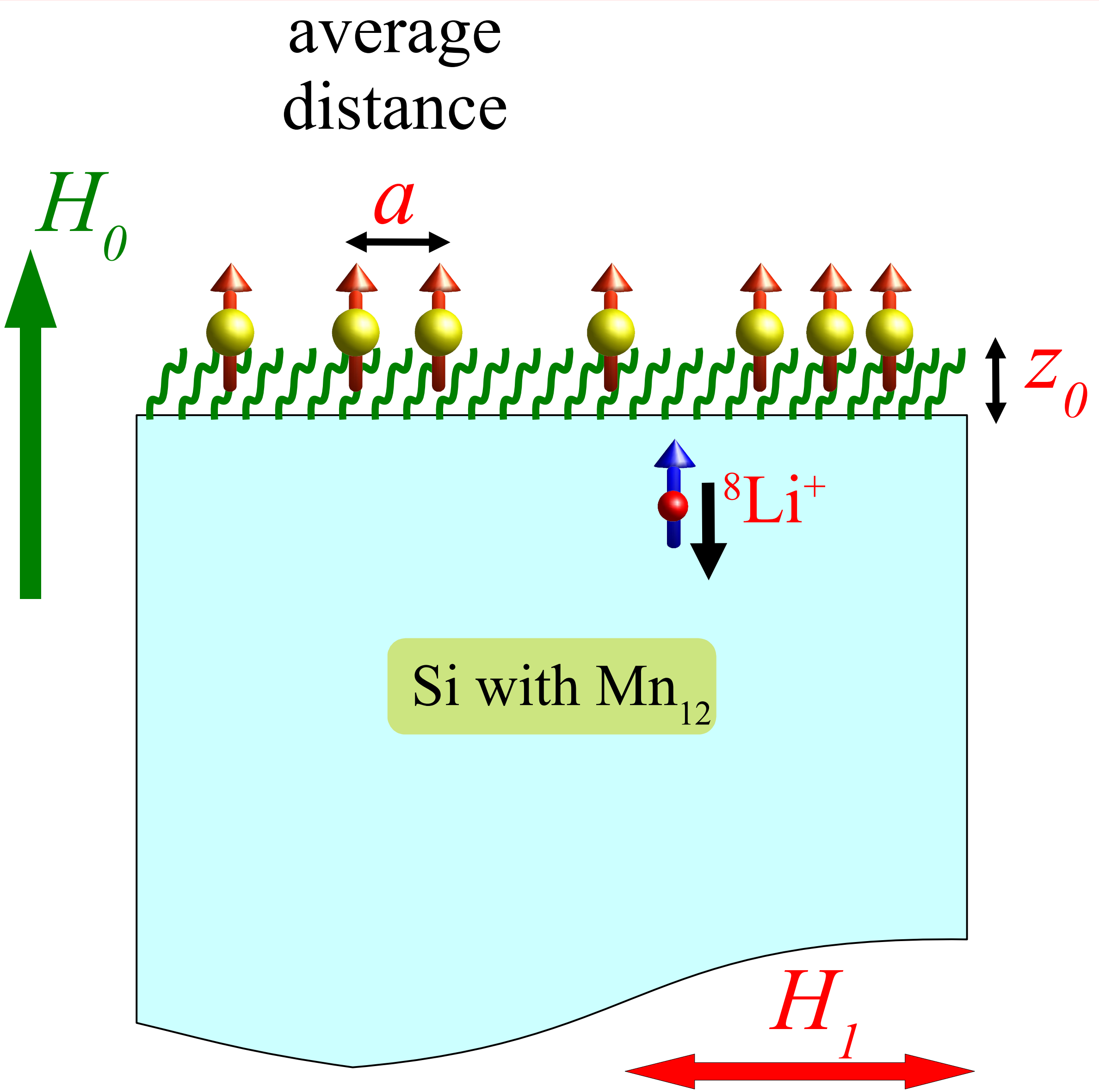


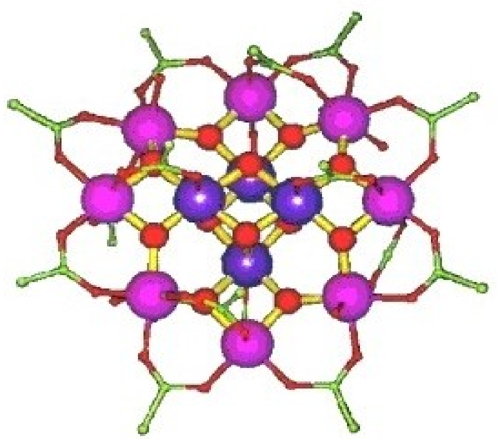
Keeler et al. PRB, in press (2008)

Example 2:

Magnetic properties of a monolayer of single molecule magnets

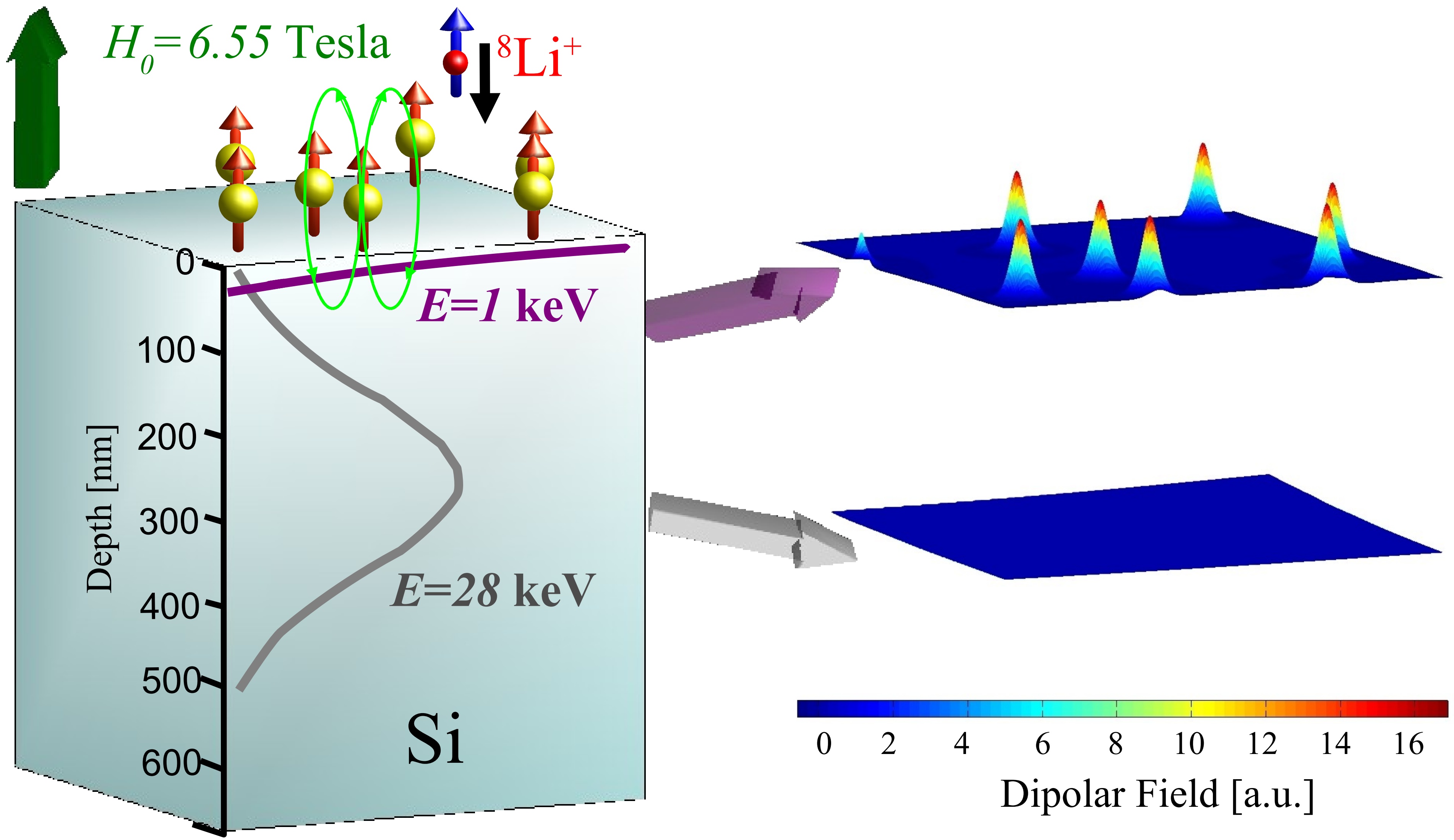
β-NMR in Mono-Layers of Mn_{12} on Si



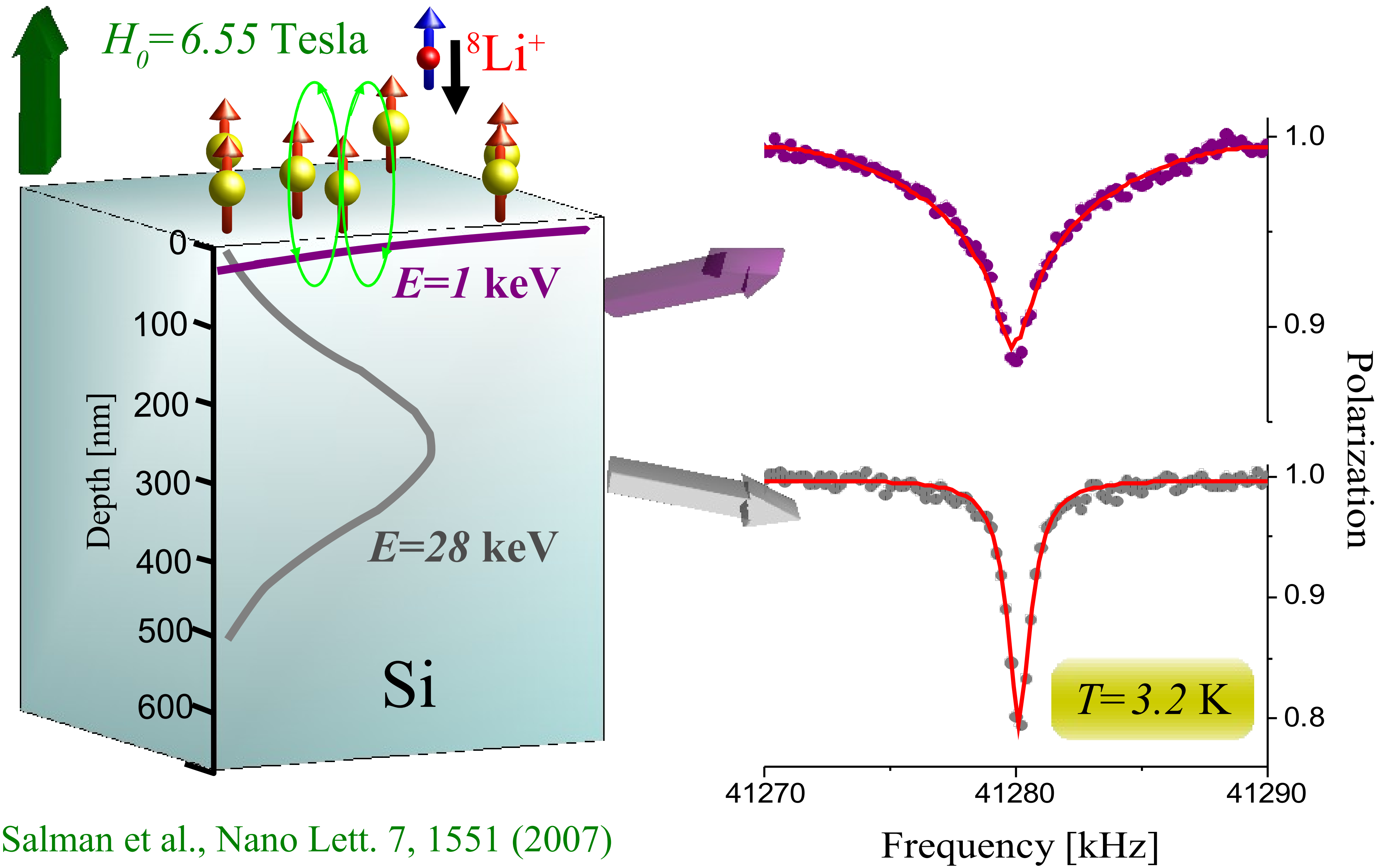


Mn_{12} - S=10

Dipolar Fields in Si

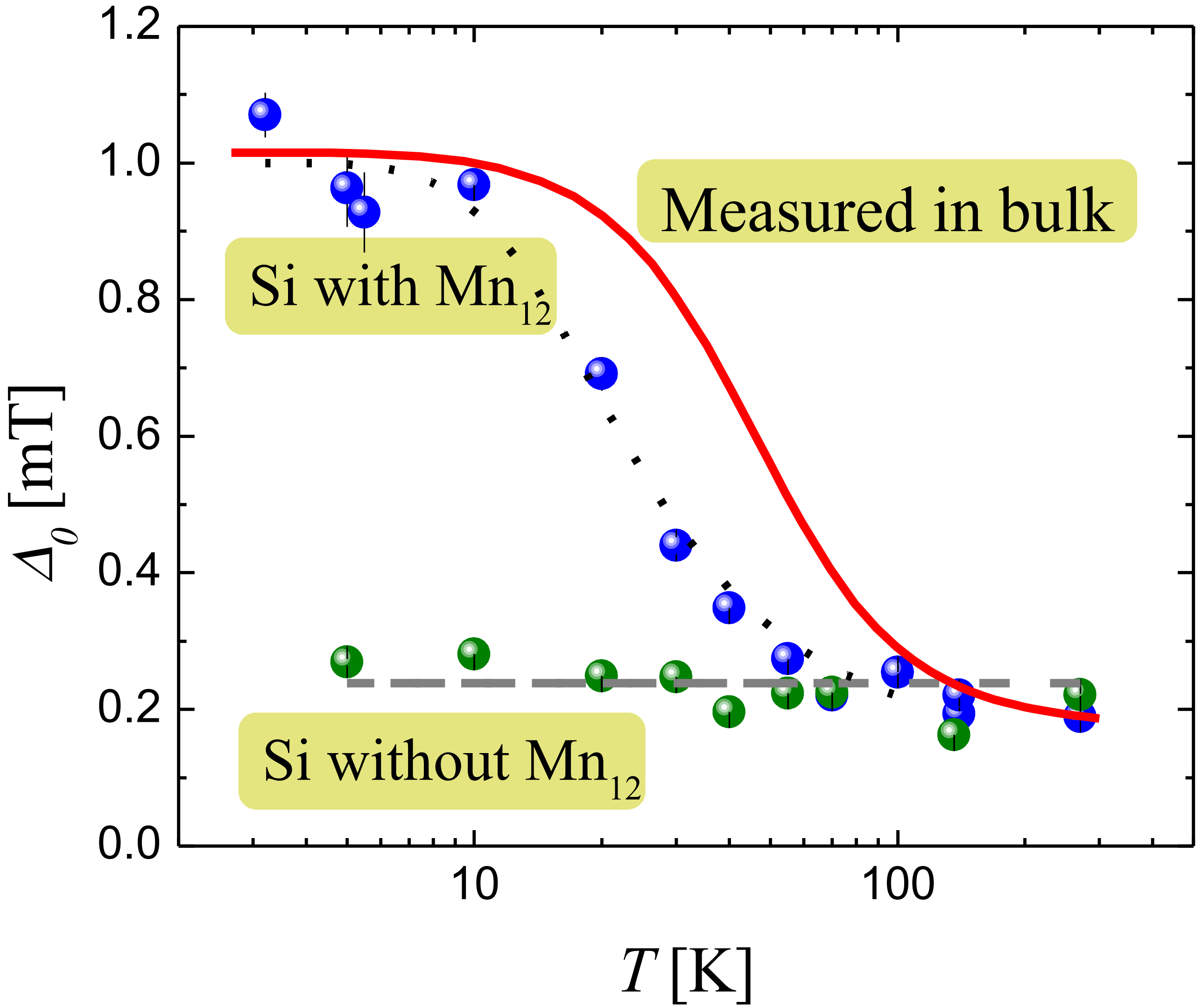


β-NMR in Mn_{12} on Si



Salman et al., Nano Lett. 7, 1551 (2007)

Resonance Broadening @ E=1keV



z_0=1.17±0.1 nm
a= 2-5 nm

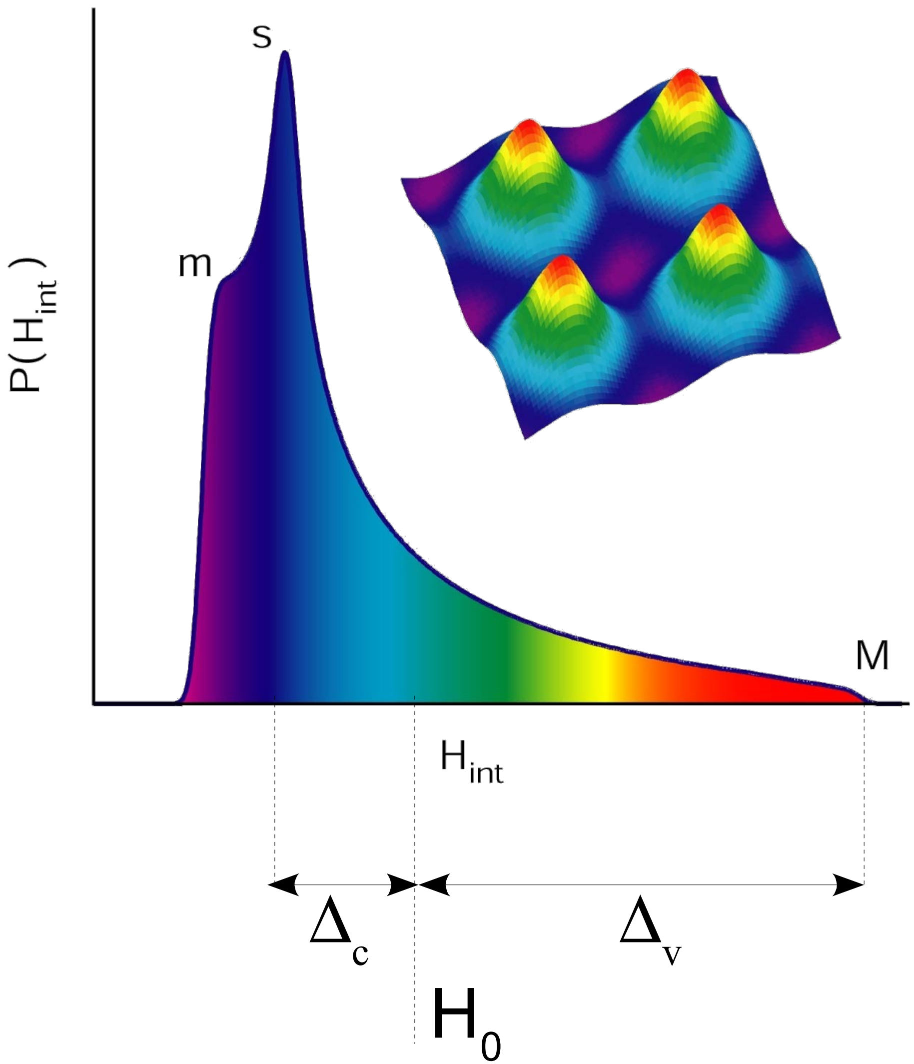
M_{ML} ~ 5-12 μ_B
M_{BULK}=20 μ_B

Salman et al., Nano Lett. 7, 1551 (2007)

Example 3:

Near surface vortex lattice in $NbSe_2$

Field distribution in a vortex lattice

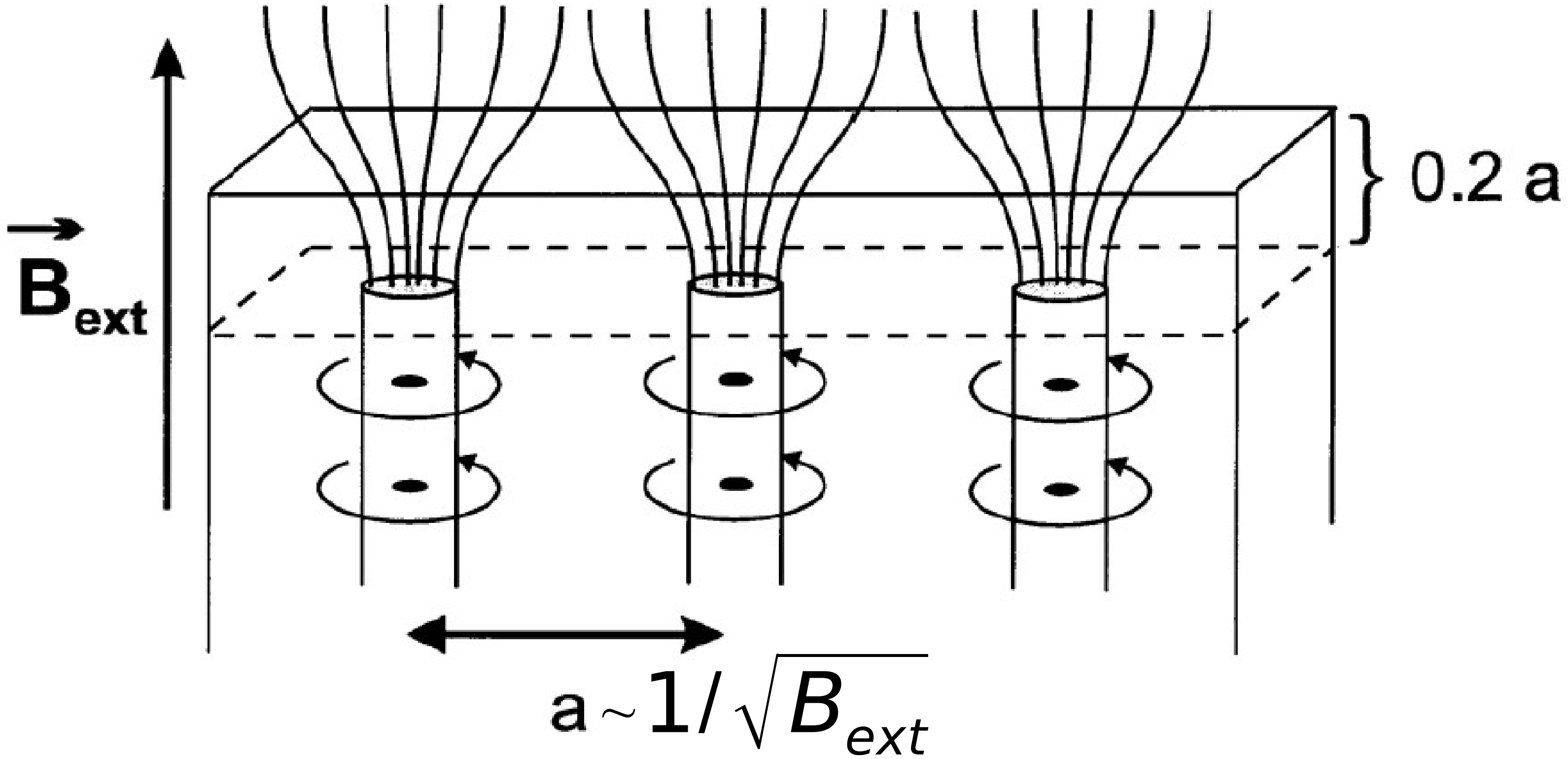


The field distribution is determined by

λ - the penetration depth

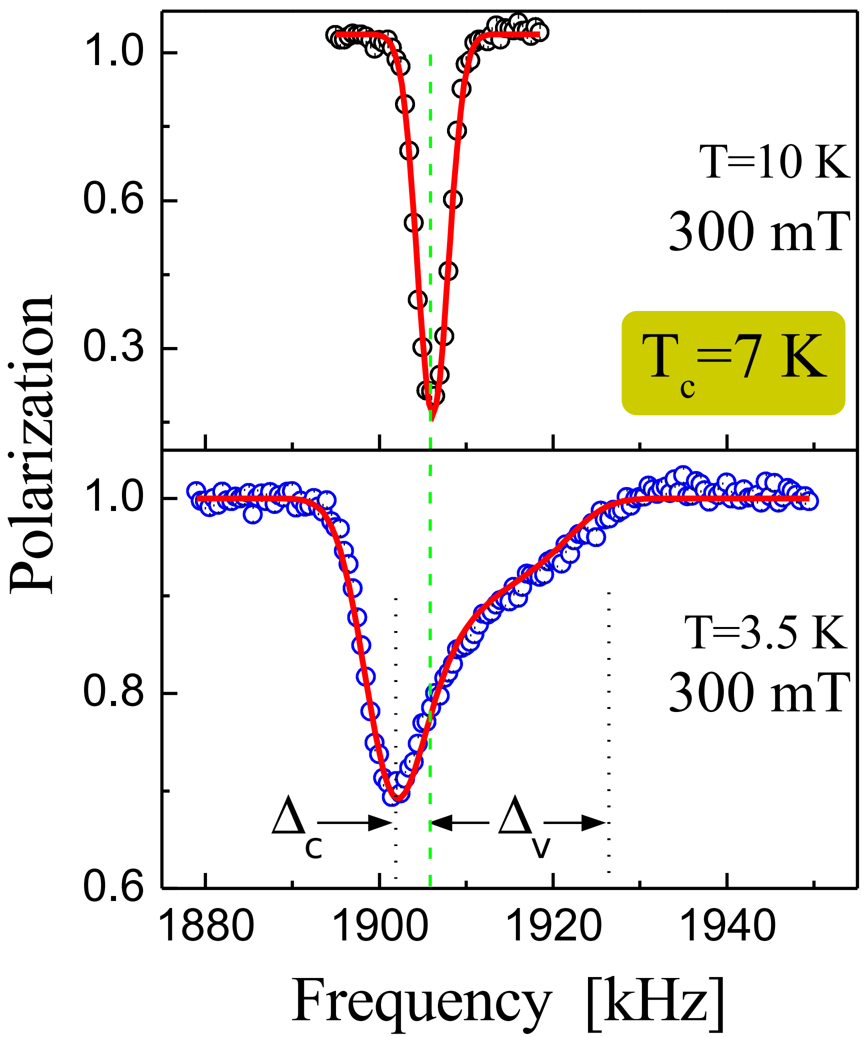
ξ - the coherence length

Vortices near a surface



Niedermayer et al. PRL **83**, 3932 (1999)

$NbSe_2$ SC state resonance line



The vortex lattice line-shape is determined by

λ – the penetration depth

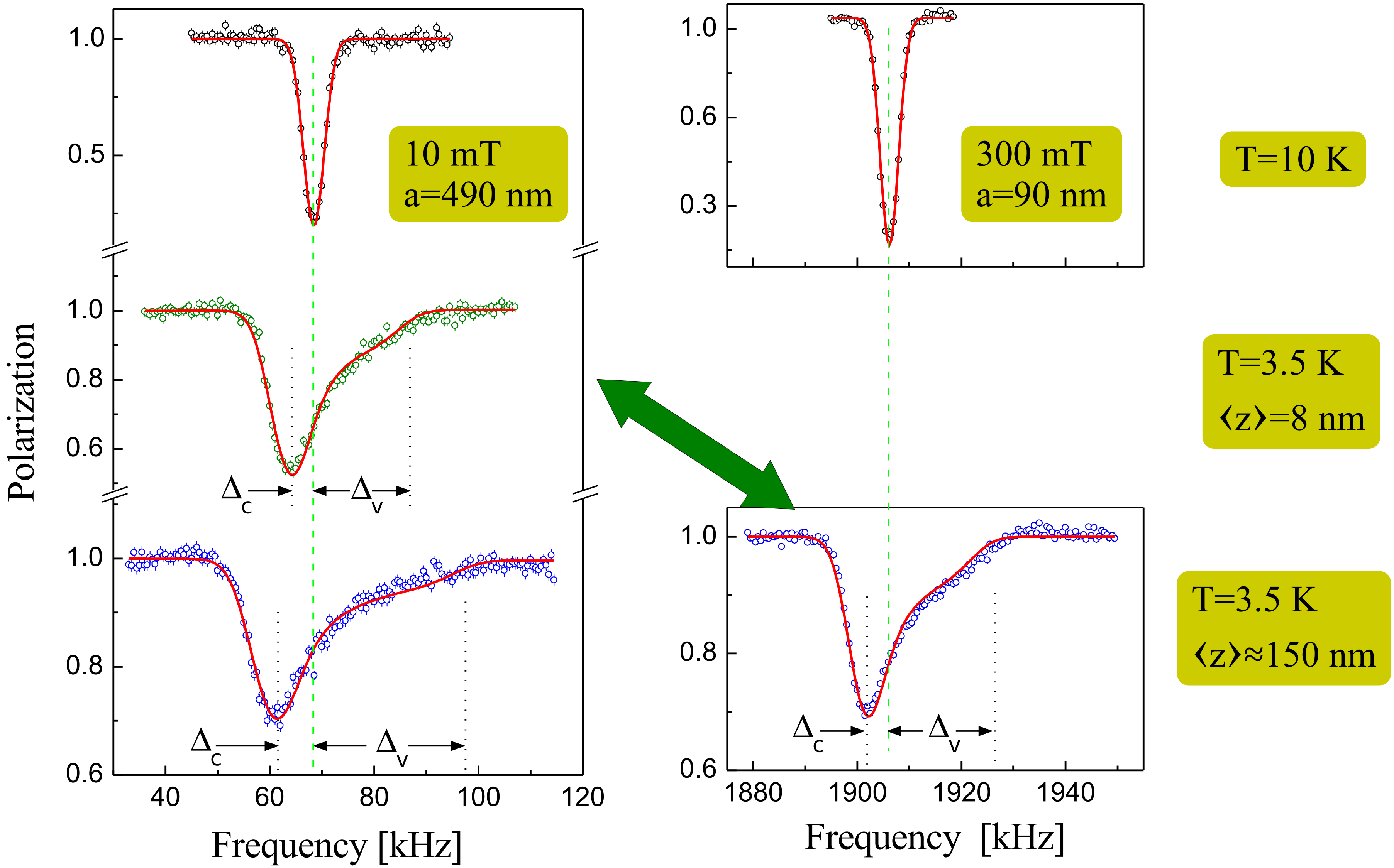
ξ/ρ – the coherence length/ core radius

λ=230(30) nm

ρ=13(1) nm

Salman et al. PRL 98, 167001 (2007)

Vortices below the surface of $NbSe_2$



Salman et al. PRL 98, 167001 (2007)

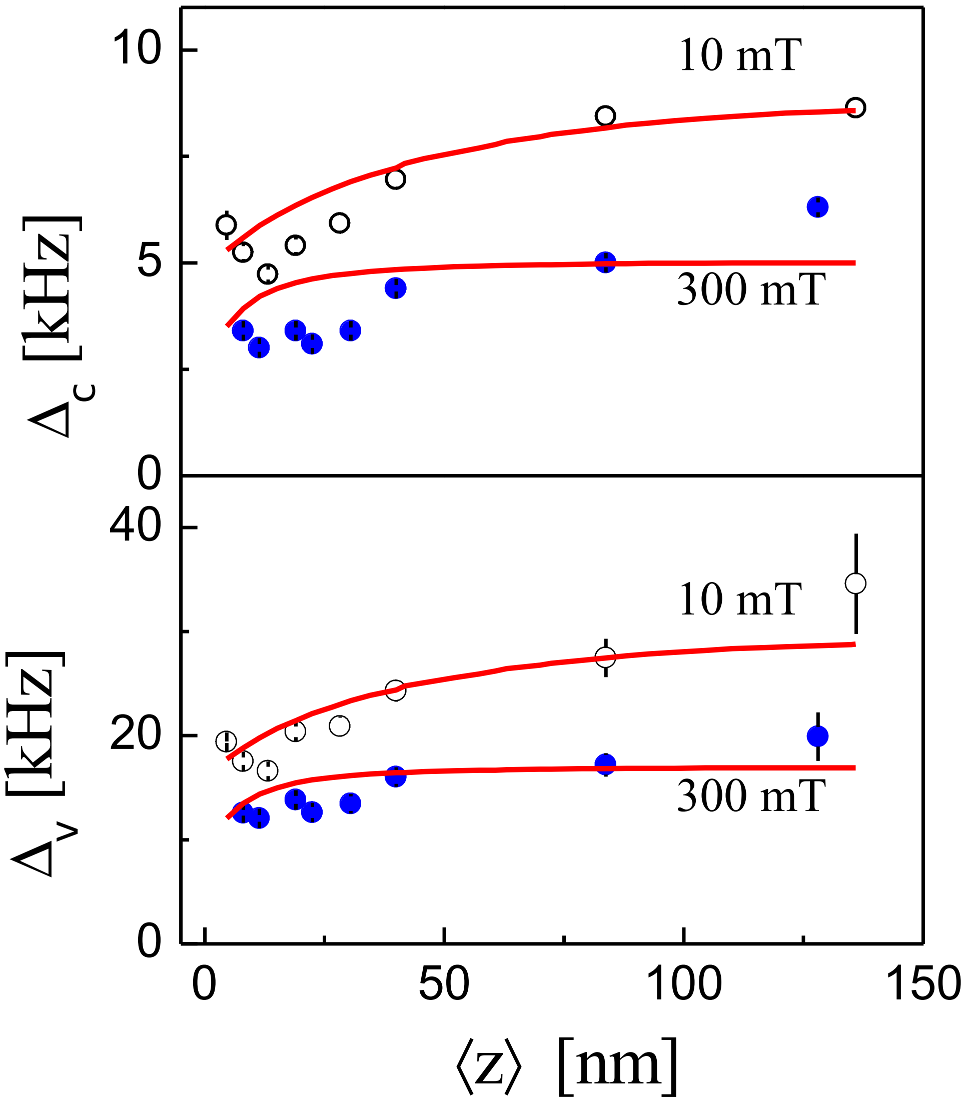
Depth dependence of the vortex lineshape in $NbSe_2$

B=300 mT
λ=230(30) nm
ρ=13(1) nm

B=10 mT
λ=167(15) nm
ρ=77(10) nm

ξ~10 nm

Vibrations of the vortices
Multi-band effects at low field



Summary and Conclusions

- Low energy β-NMR is a natural complementary technique to conventional magnetic resonance techniques, such as μSR and NMR, since it is well suited to studies of berried interfaces and thin films.
- Broad range of applications for studying depth dependence of magnetic, electronic and structural properties on a nm length scale.

Collaboration

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